Ultra-Wideband (UWB) Microstrip Bandpass Filter with an Improved Wide Stopband

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Abstract: — In this paper, the ultra-wideband (UWB) bandpass filter (BPF) with a wide stopband is presented. The prototype of proposed UWB BPF is by bending the five short-circuited stubs and coupling the I/O feed lines. In order to have a wide stopband, an bandstop structure embedded in input/output (I/O) lines without degrading the passband performances is used. The measured results verified that by using embedded bandstop structure, the proposed BPF has a wide stopband with over 30 dB rejection from 11 to 20 GHz. The experiment results of the fabricated circuit agree well with the electromagnetic (EM) simulations.

Key-words: wideband, UWB, bandpass filter, microstrip and spurious suppression

1. Introduction

In recent years, the ultra-wideband (UWB) communication systems are of great interest and wide range of applications in several communication systems [1]. Planar microstrip bandpass filters (BPFs) are key components in modern radio frequency (RF) front-end, for which the requirements of compact circuit size, high selectivity, low loss, low group delay at passband and very wide bandwidth are strongly demanded [2]. In addition, the UWB BPF should especially exhibit good passband selectivity and wide stopband in order to meet the Federal Communications Commission (FCC) requirements [1]. Moreover, typical planar distributed-based BPFs suffer from the existence of spurious responses at multiples of fundamental resonant frequencies, which may seriously degrade the RF performance of the active circuits, such as low noise amplifier (LNA) and power amplifier (PA) etc. Therefore, to suppress the spurious response to have a wide stopband is a big issue of the planar filter design consideration. There are several works have been proposed for the UWB filter [3]-[7]. In [3]-[5], a non-uniform CPW multiple-mode resonator (MMR) with short-circuited end is constructed and its first three resonant modes are properly allocated around the lower-end, center and higher-end of the specified UWB band. However, the band selectivity and spurious response is not good for this kind of filter structure. In [6], J. S. Hong reported a novel UWB BPF with pairs of transmission zeros by using five short-circuited stubs separated by nonredundant connecting lines. By introducing a cross-coupling between the feed lines, a pair of transmission zeros can be created at each side of the passband. In [7], J. S. Hong also reported a UWB BPF with embedded band

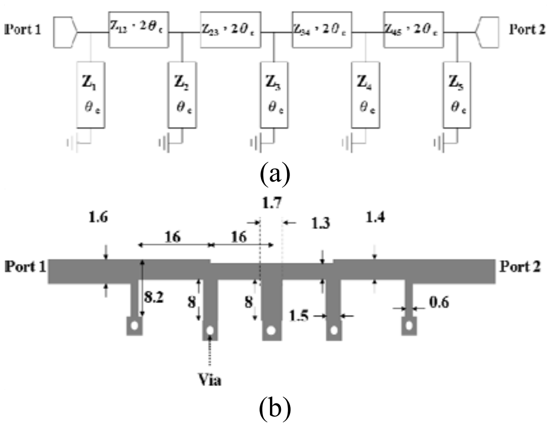


Fig. 1. (a) General circuit model for the proposed UWB BPF without coupled feed lines and (b) the layout of the UWB filter.

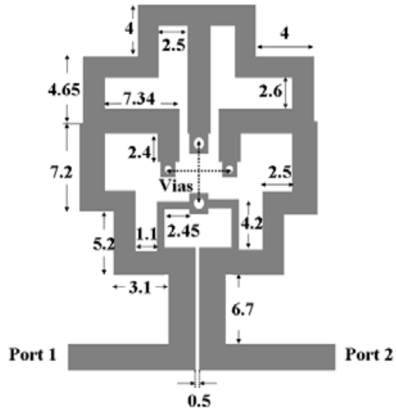


Fig. 3. Layout of the compact UWB BPF by bending the short-circuited stubs and coupling the I/O feed lines.

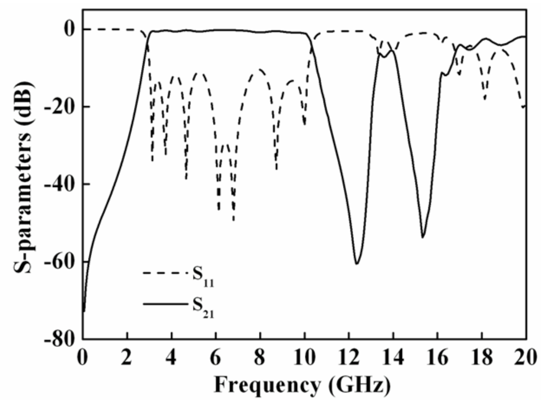


Fig. 2. Frequency response of the UWB filter as shown in Fig. 1(b).

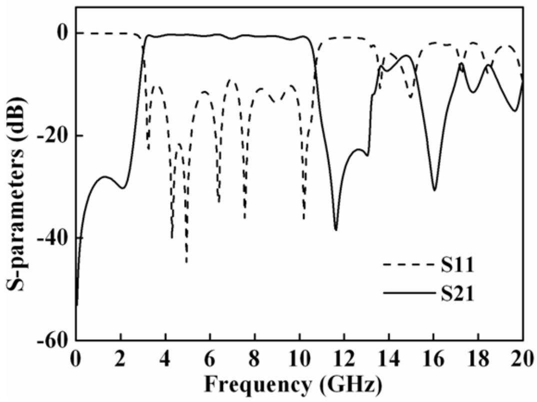


Fig. 4. Frequency response of the UWB filter with the bended structure.

notch structure to suppress the 5.7GHz of wireless local area network (WLAN). However, the spurious responses of the proposed BPF still need to be improved.

Based on the developed structure [6-7], in this paper, a UWB bandpass filter with a wide stopband by using embedded bandstop structure in input/output (I/O) lines without degrading the passband performances is presented for use in broadband wireless communication systems. The measured results of the fabricated sample are in good agreement with the EM simulation results.

2. Prototype of UWB filter design

Fig. 1(a) shows the general circuit model for the proposed UWB BPF without coupled feed lines [6]. The circuit model consists of a cascade of shunt short-circuited stub of electric length θ_c at the cutoff frequency of the passband, separated by connecting lines of electrical length $2\theta_c$. The characteristic impedance of the short-circuited stubs are defined by Z_n (n = 1 to 5), and the characteristic impedance for the connecting line are defined by $Z_{n, n+1}$ (n = 1 to 4). The terminal I/O lines impedance are defined by 50 ohm. To meet the requirements of UWB filtering component of the FCC specifications, the BPF is designed to achieve high selectivity at the band edges at 3.1 and 10.6 GHz. By using the design theory of standard highpass filter [1], the electrical length was chosen to be $\theta_c = 40.7$ for the short-circuited stubs. Based on the developed structure [6], the obtained characteristic impedances are $Z_1 = Z_5 = 87\ \Omega$, Z_2

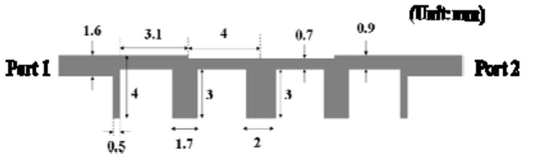


Fig. 5. Layout of the bandstop filter using five open-circuited stubs.

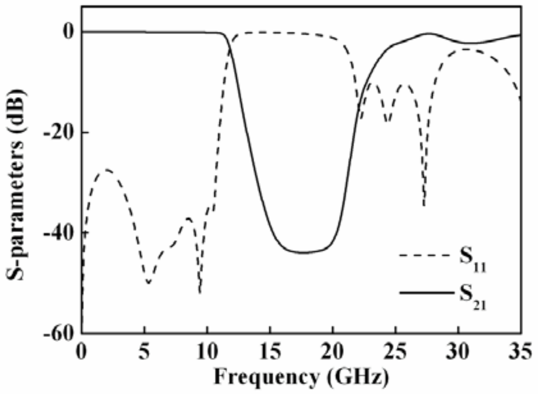


Fig. 6. Frequency response of the optimum bandstop filter shown in Fig. 5.

= Z_4 = 52.3 Ω, Z_3 = 47.4 Ω, Z_{12} = Z_{45} = 53.4 Ω and Z_{23} = Z_{34} = 56 Ω. Via holes with a diameter of 1 mm in each short-circuited stubs were used. The commercial substrate Duroid 5880 is used for this design with a relative permittivity of 2.2 and thickness of 0.508 mm. Fig. 2 shows the frequency response of the UWB filter. It is observed that the attenuation rate at the band edge is lower and spurious response appeared around 14 GHz. In order to reduce the filter size, the proposed UWB filter based on the original one is implemented by bending the short-circuited stubs and coupling the I/O feed lines, as shown in Fig. 3. The short-circuited stubs are arranged such that the first and last stubs share the same via grounding for ease the fabrication procedure. The circuit size becomes smaller and reduce s the via grounding numbers from five to four. Additionally, the cross-coupling effect is produced between the bended port 1 and port 2 [6]. As a result, the transmission zeros are produced near the edge of passband, as shown in Fig. 4. However, the spurious response is still appeared around 14 GHz.

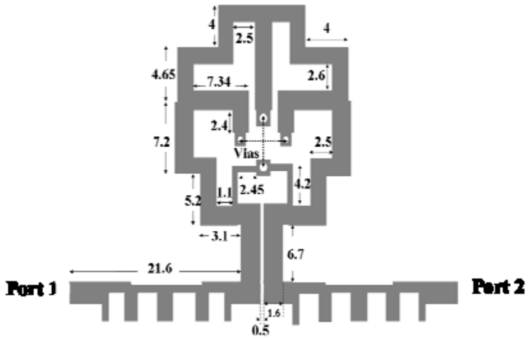
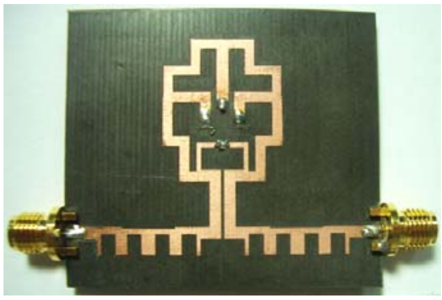
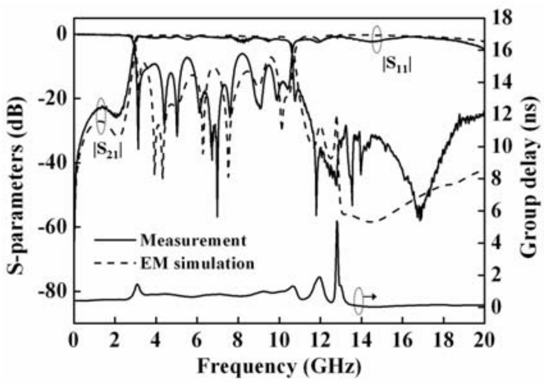


Fig. 7. Layout of the improved UWB BPF with embedded bandstop structure in input/output (I/O) lines to have a wide stopband.



(a)



(b)

Fig. 8. (a) Photograph and (b) measured results of the fabricated BPF.

3. Improving the Stopband of UWB filter prototype

In order to suppress the spurious response for achieving a wide stopband of the UWB filter, we try to use the optimum bandstop filter with five open-circuited stubs for suppressing the spurious response[1]. Fig. 5 shows the layout of the optimum bandstop filter. The bandstop filter

(BSF) is designed to have a fractional bandwidth of about 70% at a mid-stopband frequency of 17.75 GHz, which can suppress the spurious response of the UWB BPF prototype. The structural parameters of the bandstop structure are tuned by EM simulation, as shown in Fig. 5. Fig. 6 shows the stopband performance of the optimum bandstop filter. Therefore, the improved UWB BPF can be achieved, as shown in Fig. 7, by using embedded bandstop structure in input/output (I/O) lines to have a wide stopband. Even the bandstop structure is used; the size of the filter is around 30 × 45 mm^2, which is about more 50% smaller than the one in Fig. 1.

4. Results

Photograph of the fabricated BPF is shown in Fig. 8(a). The commercial substrate Duroid 5880 with a relative permittivity of 2.2 and thickness of 0.508 mm is used for this design. The fabricated BPF is measured by using a vector network analyzer HP 8510C. Fig. 8(b) shows the simulated, measured frequency responses and group delay of the BPF. The measured 3 dB fractional bandwidth (FBW) at passband is 113 %. The insertion losses $|S_{21}|$ is less than 1.1 dB at centered passband and the return losses $|S_{11}|$ is better than 30 dB. The transmission zeros at around 2 and 10 GHz are clearly observed, which gives nearly -20 dB isolation. The flat group delay of about 1ns is obtained over the entire passband. Moreover, the proposed BPF has a wide stopband with over 30 dB rejection from 11 to 20 GHz for avoiding other RF interferences into the UWB system. It is clearly verified that embedding the bandstop structure in the I/O ports does nor degrade the passband performances but actually well suppress the unwanted spurious responses. The slight differences between the simulations and measurements might be due to fabrication errors or the variation of material properties. The superior features indicate that the proposed UWB BPF has potential to be utilized in broadband wireless applications.

5. Conclusion

In this paper, the improved UWB BPF with a wide stopband has been proposed and carefully examined. The proposed BPF prototype is based on a circuit model of five shorted stubs. To improve the stopband of the UWB BPF, a bandstop filter using five open-circuited stubs is integrated in the I/O lines. The fabricated BPF showed the low loss and a flat group delay over the passband and a very good performance on the out-of-band. The proposed BPF is useful for applications in UWB communication systems.

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